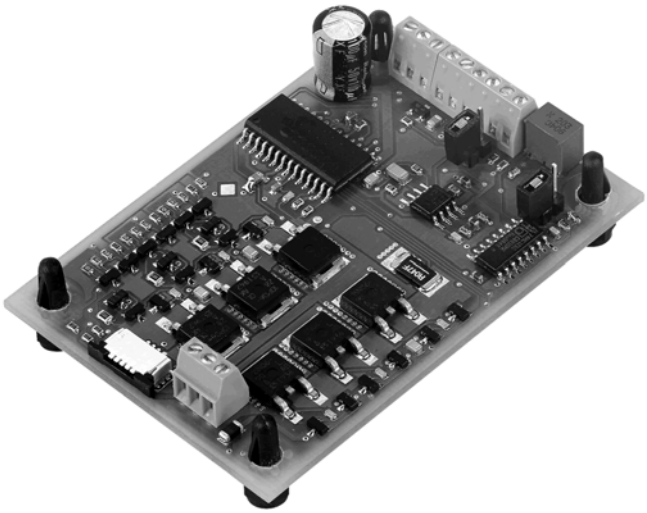
maxon motor

maxon motor control 1-Q-EC Amplifier AECS 35/3

Order number 215738

Operating Instructions April 2006 Edition

The AECS (**A**nalogue **E**C **C**ontroller **S**ensorless) is a 1-quadrant EC amplifier for controlling electronically commutated (brushless) DC motors.
Rotor position sensors (Hall sensors) are not required.



- The electronics are flexible to use due to their wide input voltage range (8 - 35 VDC).
- A fixed current limitation restricts motor current to 5 A max.
- Motor speed is regulated and if required, can be adjusted by the built-in potentiometer or an externally predetermined set value.
- Speed can be monitored through the speed monitor output.
- A “Brake” input allows the motor shaft to slow down to a halt.
- The „Direction” input adjusts motor direction.
- The “Disable” input can interrupt the power supply to the motor.
- Motor connection either by using screw terminals or flex print connector (for maxon flat motors).
- The current rotor position is evaluated by using the back-EMF sensing technique.
- The integrated power MOS-FET power stage produces a high efficiency level.

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The latest edition of these operating instructions may be downloaded from the internet as a PDF-file under www.maxonmotor.com, category «Service & Downloads», Order number 215738.

1 Safety Instructions

Skilled Personnel
Only experienced, skilled personnel should install and start the equipment.

Statutory regulations
The user must ensure that the amplifier and the components belonging to it are assembled and connected according to local statutory regulations.

Load disconnected
For initial operation, the motor should be free running, i.e. with the load disconnected.

Additional safety equipment
Any electronic apparatus is, in principle, not fail-safe. Machines and apparatus must therefore be fitted with independent monitoring and safety equipment. If the equipment breaks down, if it is operated incorrectly, if the control unit breaks down or if the cables break, etc., it must be ensured that the drive or the complete apparatus is kept in a safe operating mode.

Repairs
Repairs may only be carried out by authorised personnel or the manufacturer. It is dangerous for the user to carry out any repairs.

Danger
Ensure that no apparatus is connected to the electrical supply during installation of the AECS 35/3. After switching on, do not touch any live parts!

Wiring procedure
All cable connections should only be connected or disconnected when the power is switched off.

Max. supply voltage
Make sure that the supply voltage is between 8 and 35 VDC. Voltages higher than 35 VDC or of wrong polarity will destroy the unit.

Start-up procedure
Start-up problems may occur in unfavourable applications through the principle of sensorless commutation. This is the case with high friction torque, a very high load moment of intertia and in general, applications of flat motors operated at high voltages (above motor's nominal voltage).

Electrostatic sensitive device (ESD)

2 Performance Data

2.1 Electrical data

Supply voltage V_{CC} ..... 8 - 35 VDC
Continuous output current I_{cont} ..... 3 A
Max. output current I_{max} (limited internally) ..... 5 A
Switching frequency of power stage ..... typ. 40 kHz
Speed range (motor with 1 pole pair) ..... typ. 1000 ... 90 000 rpm

2.2 Inputs

Direction ..... logic signal (5 V) or switch against Gnd
Open or high level = clockwise
at Gnd = counter-clockwise
Brake ..... logic signal (5 V) or switch against Gnd
Open or high level = motor shaft turns
at Gnd = motor shaft stops
Disable ..... logic signal (5 V)
Open or low level = motor shaft turns
High level = motor is separated from supply
Set value ..... analogue input (0.8 ... 5 V)

2.3 Outputs

Monitor n ..... open collector (pull-up 22 kΩ at 5 V, 10 mA)
Speed monitoring NOS ..... open collector (pull-up 4.7 kΩ at 5 V, 10 mA)
Control voltage OUT ..... analogue output (0 ... 5 V)

2.4 Motor connections

Motor winding 1
Motor winding 2
Motor winding 3

2.5 Ambient temperature / humidity range

Operation ..... 0 ... +40°C
Storage ..... -40 ... +85°C
No condensation ..... 20 ... 80 %

2.6 Mechanical data

Weight ..... approx. 20 g
Dimensions (L x W x H) ..... 74 x 51 x 20 mm
Fastening ..... 4 distance pins hexagonal M3 internal thread
Mounting hole separation ..... 63.2 x 40.6 mm

2.7 Terminals

Power / Signal

Screw terminals J1 ..... 9 poles
Pitch ..... 2.54 mm
AWG 26-20 ..... 0.14 ... 0.5 mm^2

Motor terminal

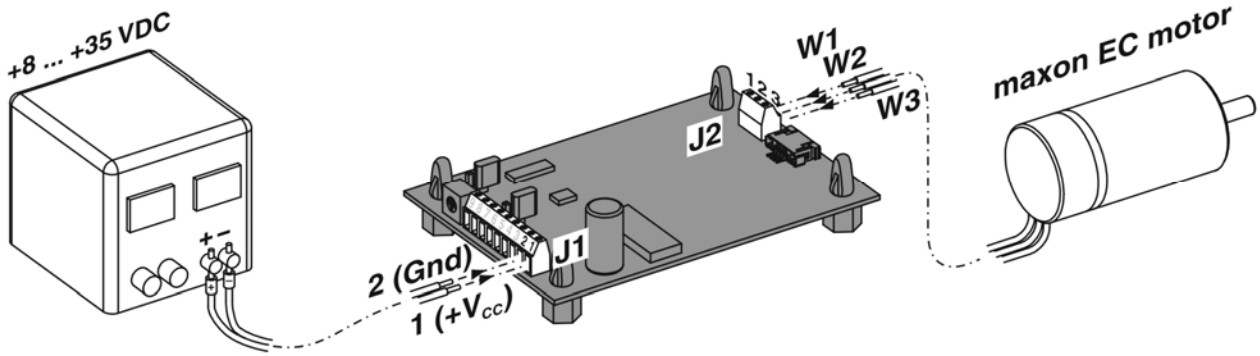
Screw terminals J2 ..... 3 poles
Pitch ..... 2.54 mm
AWG 26-20 ..... 0.14 ... 0.5 mm^2

Flex print connector J3 ..... 4 poles
Pitch ..... 1.0 mm

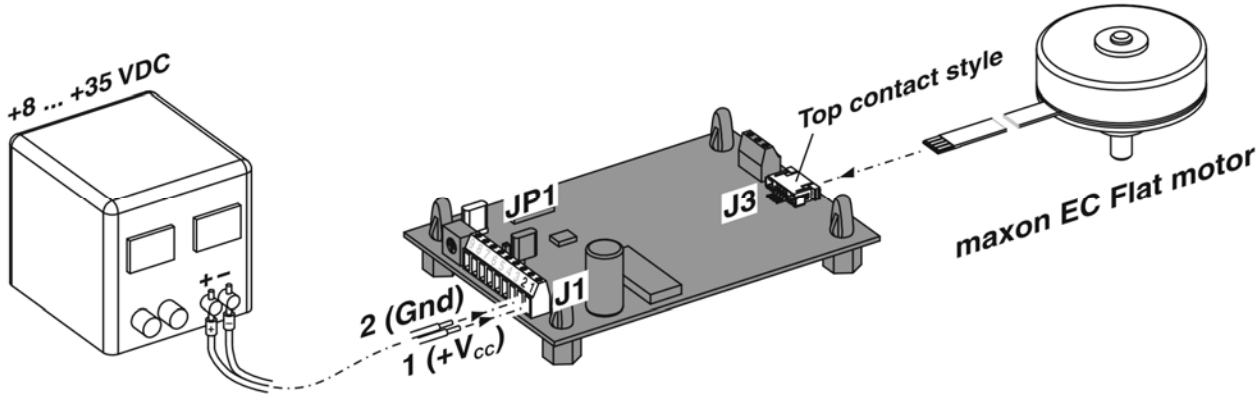
3 Minimum External Wiring

3.1 Power Supply / Motor

Application with maxon EC motor

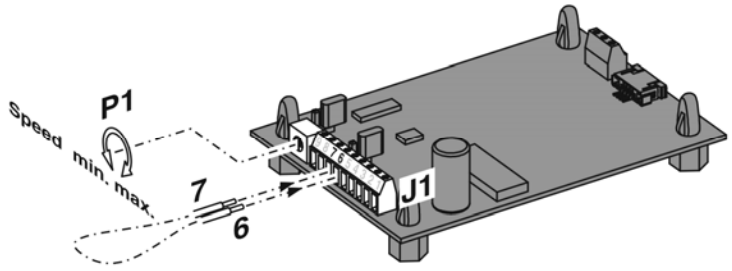


Application with maxon EC Flat motor

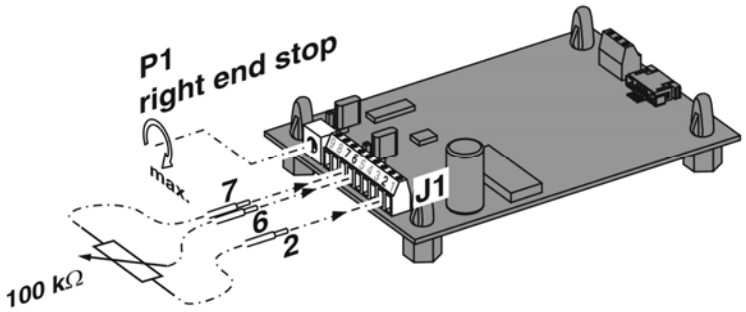


3.2 Set value input

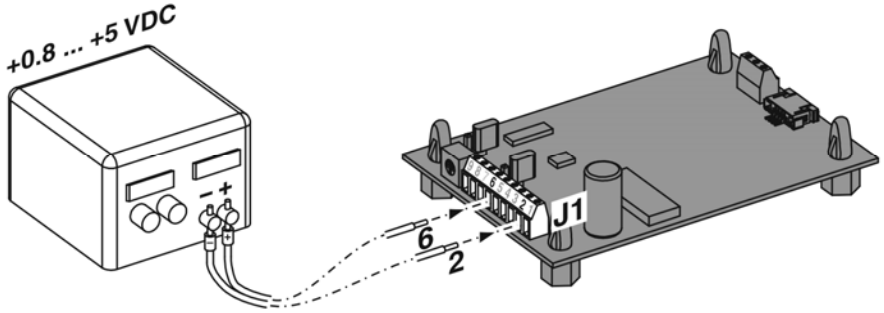
with internal potentiometer P1



with external potentiometer



with external set value +0.8 … +5 V



4 Operating Instructions

4.1 Power supply layout

Any available power supply can be used, as long as it meets the minimum requirements set out below.
During set up and adjustment phases, we recommend separating the motor mechanically from the machine to prevent damage from uncontrolled motion.

Power supply requirements	
Output voltage	V_{CC} min. 8 VDC; V_{CC} max. 35 VDC
Ripple	< 5 %
Output current	depending on load, continuous max. 3 A acceleration, short-time max. 5 A

The required voltage can be calculated as follows:
Known values:
- Operating torque M_B [mNm]
- Operating speed n_B [rpm]
- Nominal motor voltage U_N [V]
- Motor no-load speed at U_N, n_0 [rpm]
- Speed/torque gradient of motor $\Delta n/\Delta M$ [rpm/mNm]

Sought values:
- Supply voltage V_{CC} [V]

Solution:

$$V_{cc} = \frac{U_N}{n_0} \cdot (n_B + \frac{\Delta n}{\Delta M} \cdot M_B) + 1.5V$$

Choose a power supply that can supply this calculated voltage under load.
The formula takes account of a 1.5 max. voltage drop at power stage.

What speed do I reach with my power supply:

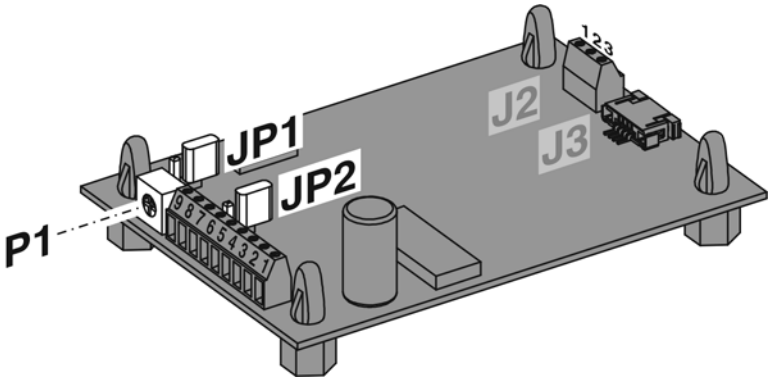
$$n_B = \left[(V_{CC} - 1.5\,V) \cdot \frac{n_0}{U_N} \right] - \left[\frac{\Delta n}{\Delta M} \cdot M_B \right]$$

Note:
Please note chapter 6.1.2, „Brake” when using the “Brake” input!

4.2 Pre-adjustment

With the pre-adjustment, the potentiometers are set in a preferred position.

AECS units in the original packing are already pre-set.



Pre-adjustment		
P1	Speed	**50%**
JP1	Speed range	**open**
JP2	Speed mode	**open**

5 Functions and Signals

5.1 Start-up procedure

Depending on the rotor start position and size of the coupled load, there is a short build-up procedure prior to the motor's run-up.

During the start-up procedure, the motor shaft may temporarily make right-left rotary motions!

The following points are detrimental to the start-up procedure:

- high friction torque
- very high load moment of intertia
- high voltages (above motor's nominal voltage)

Note:

Start-up problems may occur in unfavourable applications through the principle of sensorless commutation.

Multipole motors (maxon EC flat motors) should only be run with a closed JP1 built-in jumper, otherwise the control amplification would be too high and the speed controller starts to oscillate.

This behavior is particularly noticeable in maxon flat motors. (V_{CC} > motor nominal voltage)

5.2 Current limitation

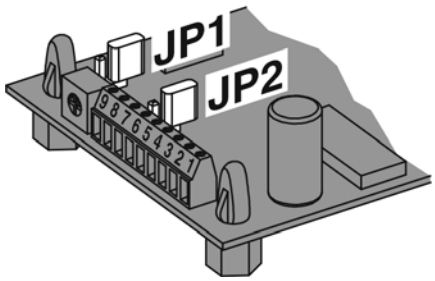
The AECS's current limitation is around 5 A, in which operation is permissible during max. 20 s. The maximum continuous current is 3 A, otherwise thermal overload would occur. The AECS's power stage and motor are not protected against thermal overload.

5.3 Speed range, Jumper JP1

The maximum speed is limited by the supply voltage and the speed that can be best adjusted at the set value input.

Jumper JP1 allows two speed ranges:

Jumper JP1	Maximum speed		
	Motor with 1 pole pair	Motor with 4 pole pairs	Motor with 8 pole pairs
open 	12 000 rpm	3 250 rpm	1 625 rpm
closed 	90 000 rpm	22 500 rpm	11 250 rpm



Important:
Some motor types allow only one speed range. See maxon catalogue “Max permissible speed”.

Multipole motors (maxon EC flat motors) should only be operated with a closed JP1 built-in jumper, otherwise the control amplification would be too high and the speed controller would start to oscillate.

The motor voltage cannot be reduced to 0 V because of the commutation process, therefore the motor must be operated at a minimum speed, depending on operating voltage, load and motor type.
The minimum speed is determined by the speed constants and minimum motor voltage. The AECS’s minimum motor voltage is around 10% of operating voltage.

Example: V_{CC} = 24 V, k_n = 195 rpm V^{-1}
=> Motor voltage U_M = 2.4 V, n_{min} = approx. 500 rpm

5.4 Speed mode, Jumper JP2

Speed control is deactivated by closing jumper JP2. The motor turns with the maximum speed.

Jumper JP2	Speed mode
open 	Speed control (closed loop)
closed 	True commutation

6 Inputs and Outputs

6.1 Inputs

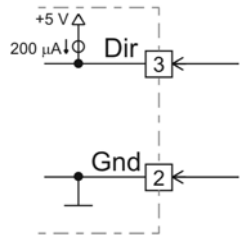
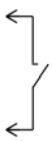
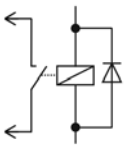
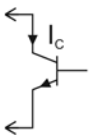
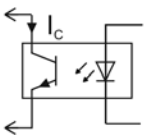
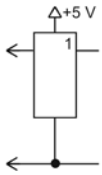
6.1.1 „Direction“

The motor shaft’s direction is predetermined through the „Direction” input.

Input voltage range	0 ... +5 V
Input current	max. -200 µA (internal current source at +5 V)
Overvoltage protection	not protected

Clockwise (CW)	Input open or input voltage > 4.0 V
Counter-clockwise (CCW)	Set input to Gnd or input voltage < 1.0 V

Wiring examples:

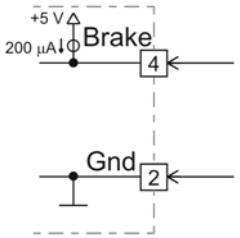
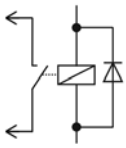
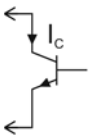
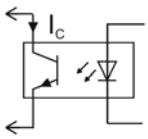
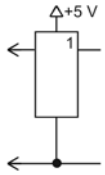
	Switch	**Relay contact**	**NPN transistor**	**Optocoupler**	**Logic component**
					
Clockwise (CW)	Switch open	Contact open	Transistor blocked $I_C = 0$	Transistor blocked $I_C = 0$	HIGH Level > 4.0 V
Counter-clockwise (CCW)	Switch closed	Contact closed	Transistor conductive $I_C = 200$ µA	Transistor conductive $I_C = 200$ µA	LOW Level < 1.0 V

6.1.2 „Brake“

If the input is not wired or the applied voltage is greater than 4.0 V, the brake function is deactivated.
If the input is placed at Gnd-potential or the applied voltage is lower than 1.0 V, the brake function is activated and the motor shaft slows down to a halt, short-circuiting the motor windings. The motor windings remain short-circuited until the brake function is deactivated.

Input voltage range	0 ... +5 V
Input current	max. -200 µA (internal current source at +5 V)
Overvoltage protection	Not protected
Brake function not active	Input open or input voltage > 4.0 V
Brake function aktive	Set input to Gnd or input voltage < 1.0 V

Wiring examples:

	Switch	Relay contact	NPN transistor	Optocoupler	Logic component
					
Brake function not active	Switch open	Contact open	Transistor blocked $I_C = 0$	Transistor blocked $I_C = 0$	HIGH Level > 4.0 V
Brake function active	Switch closed	Contact closed	Transistor conductive I_C = 200 µA	Transistor conductive I_C = 200 µA	LOW Level < 1.0 V

The maximum permitted brake speed is limited by the maximum permitted short-circuit current and maximum kinetic energy:

- I <= 10 A
- W_k <= 20 Ws

The values can be calculated as follows:

max. permitted brake speed limited by brake current (I = 10 A)

The maximum permitted brake speed can be calculated from the motor data:

$$n_{\max} = 10A \cdot k_n \cdot \left(R_{Ph-Ph} + 0.13\Omega\right) \qquad [rpm]$$

k_n = Speed constant [rpm·V^{-1}]
R_{Ph-Ph} = Terminal resistance phase-phase [Ω]

max. permitted brake speed limited by kinetic energy (W_k = 20 Ws)

With the given moment of inertia, the maximum speed can be determined using the following formula:

$$n_{\max} = \sqrt{\frac{365}{J_R + J_L}} \cdot 10\,000 \qquad [rpm]$$

J_R = Rotor inertia [g·cm^2]
J_L = Load inertia [g·cm^2]

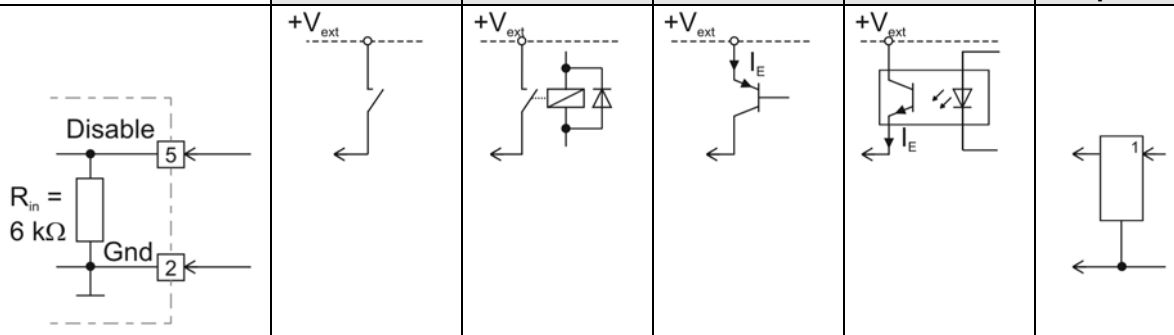
6.1.3 „Disable“

Enable or disable the power stage. If the input "Disable" is not wired or placed at Gnd-potential or the applied voltage is lower than 0.4 V, the amplifier is activated. If the applied voltage is greater than 2.4 V, the power stage is blocked and the motor shaft freewheels and slows down.
The “Disable” input is protected against overvoltage.

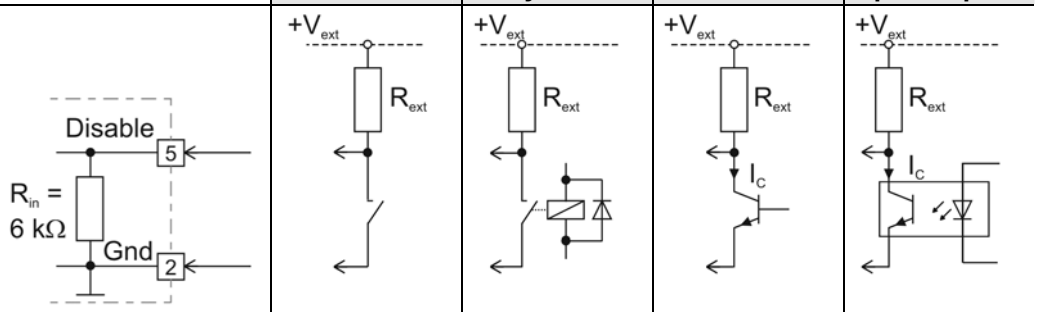
Input voltage range	0 ... +24 VDC
Input impedance	approx. 6 kΩ resistance against Gnd
Max. input voltage	0 ... +25 VDC

Power stage active	Input open or set to Gnd or input voltage < 0.4 V
Power stage inactive	Input voltage > 2.4 V

Wiring examples:
a) switch open = „Enable“; switch closed = „Disable“

	Switch	Relay contact	NPN transistor	Optocoupler	Logic component
					
Power stage active Motor winding fed with current	Switch open	Contact open	Transistor blocked $I_E = 0$	Transistor blocked $I_E = 0$	LOW Level
Power stage inactive Motor shaft freewheels and slows down	Switch closed	Contact closed	Transistor conductive $I_E > 0$	Transistor conductive $I_E > 0$	HIGH Level

b) switch open = „Disable“; switch closed = „Enable“

	Switch	Relay contact	NPN transistor	Optocoupler
				
Power stage active Motor winding fed with current	Switch closed	Contact closed	Transistor conductive $I_C > 0$	Transistor conductive $I_C > 0$
Power stage inactive Motor shaft freewheels and slows down	Switch open	Contact open	Transistor blocked $I_C = 0$	Transistor blocked $I_C = 0$

Calculation help **Known value:** $+V_{ext}$ = +3.3 … +24 VDC

Sought value:

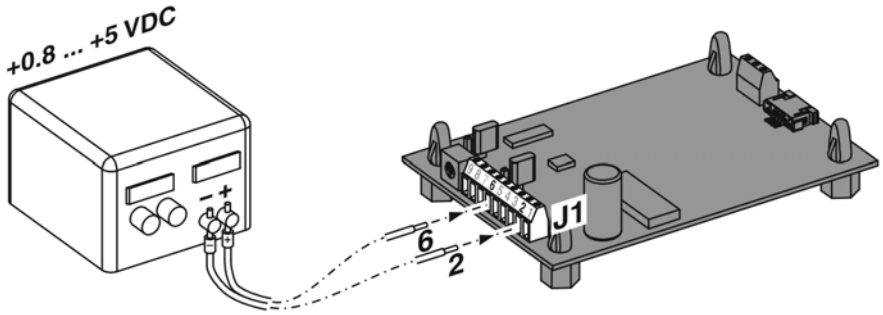
$$R_{ext} \leq \left(\frac{V_{ext}}{2.4\,V} \cdot 6000\,\Omega \right) - 6000\,\Omega \quad [\Omega]$$

6.1.4 "Set value"

Set value input via external power supply

The voltage at the "Set value" input predetermines the speed set value.
The speed changes proportionately to the set value.

Input voltage range	0.8 ... +5 V (reference against Gnd)
Input impedance	> 1M Ω
Overvoltage protection	not protected

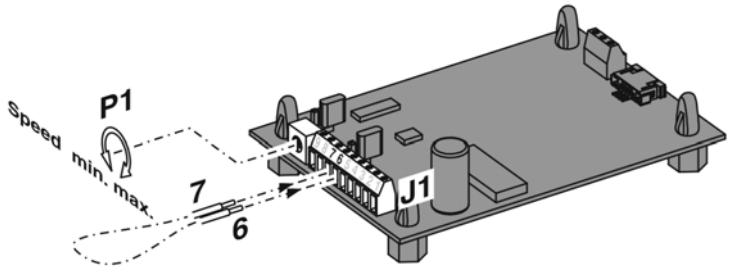


Set value input via internal potentiometer P1

The "Set value" input (J1, clamp 6) must be connected to the „Control voltage OUT" output (J1, clamp 7).

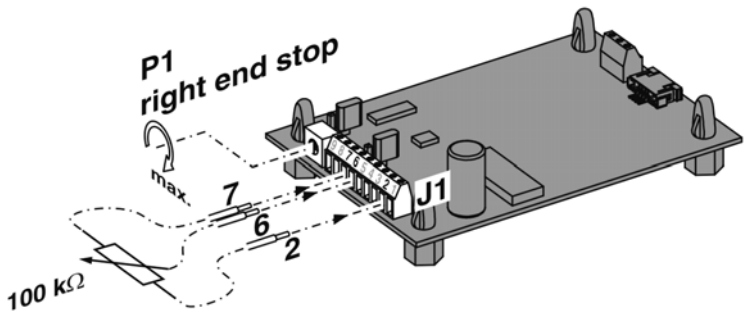
Note:

The lower and upper limitation of speed adjustment must be observed (see chapter 5.3, "Speed range, Jumper JP1").



Set value input via external potentiometer

Internal potentiometer P1 at right end stop	
Value of external potentiometer	100 kΩ



6.2 Outputs

6.2.1 „Control voltage OUT“

If the internal potentiometer P1 is used for speed adjustment, the “Control voltage OUT” output (clamp 7) must be electrically connected to the „Set value” input (clamp 6).

Output voltage range	0 ... +5 V
Output impedance	approx. 10 kΩ
Potentiometer P1 right end stop	+5 VDC
Potentiometer P1 left end stop	0 V

6.2.2 Speed monitor „NOS“

The NOS output (**N**on **O**perating **S**ignal) can be used for status monitoring.

Output voltage range	0 ... +5 V
Output current	max. 10 mA against Gnd
Voltage value 'low'	Motor shaft turns max. 0.3 V
Voltage value 'high'	Motor shaft stops +5 V (4.7 kΩ internal pull-up resistor at +5 V)

Note:
Cable failure or lack of supply voltage cannot be monitored!
'High' level is displayed during the motor’s start-up cycle.

6.2.3 „Monitor n“

The motor shaft's set speed can be monitored at the electronics „Monitor n” output. The set speed is available as a digital signal (high/low) and corresponds to half the commutation frequency.

Output voltage range	0 ... +5 V
Output current	max. 10 mA against Gnd
Voltage value 'low'	max. 0.3 V
Voltage value 'high'	+5 V (22 kΩ internal pull-up resistor at +5 V)

Sought: frequency at the „Monitor n” output

$$f_{Monitor\ n} = \frac{n_{set} \cdot z_{Pol}}{20} \quad [Hz]$$

n_{set} = Speed [rpm]
z_{Pol} = Number of the motor's pole pairs

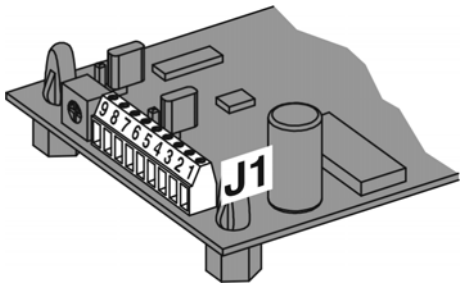
Sought: motor shaft speed

$$n_{set} = \frac{f_{Monitor\ n} \cdot 20}{z_{Pol}} \quad [rpm]$$

$f_{Monitor\ n}$ = Frequency at the „Monitor n” output [Hz]
z_{Pol} = Number of the motor's pole pairs

7 Pin assignment

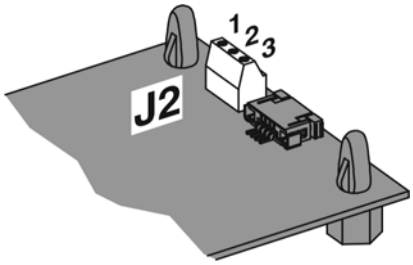
7.1 Pin assignment J1 Power / Signal



9	Monitor n
8	Speed monitoring NOS
7	Control voltage OUT
6	Set value
5	Disable
4	Brake
3	Direction
2	Gnd
1	$+V_{CC}$ 8 … 35VDC

Screw terminal	9 poles
Pitch	2.54 mm
AWG 26-20	0.14 ... 0.5 mm^2

7.2 Pin assignment J2 motor connection



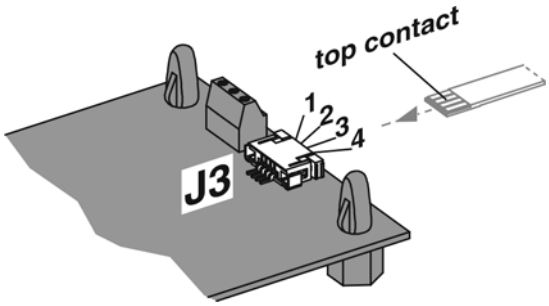
1	Motor winding 1
2	Motor winding 2
3	Motor winding 3

Screw terminal	3 poles
Pitch	2.54 mm
AWG 26-20	0.14 ... 0.5 mm^2

Note:

Motor terminals matching, e.g:	maxon EC motor	EC∅16 sensorless
	maxon EC motor	EC∅22 sensorless
	maxon EC motor	EC∅32
	maxon EC motor	EC∅40

7.3 Pin assignment J3 (4 poles flex print connector)



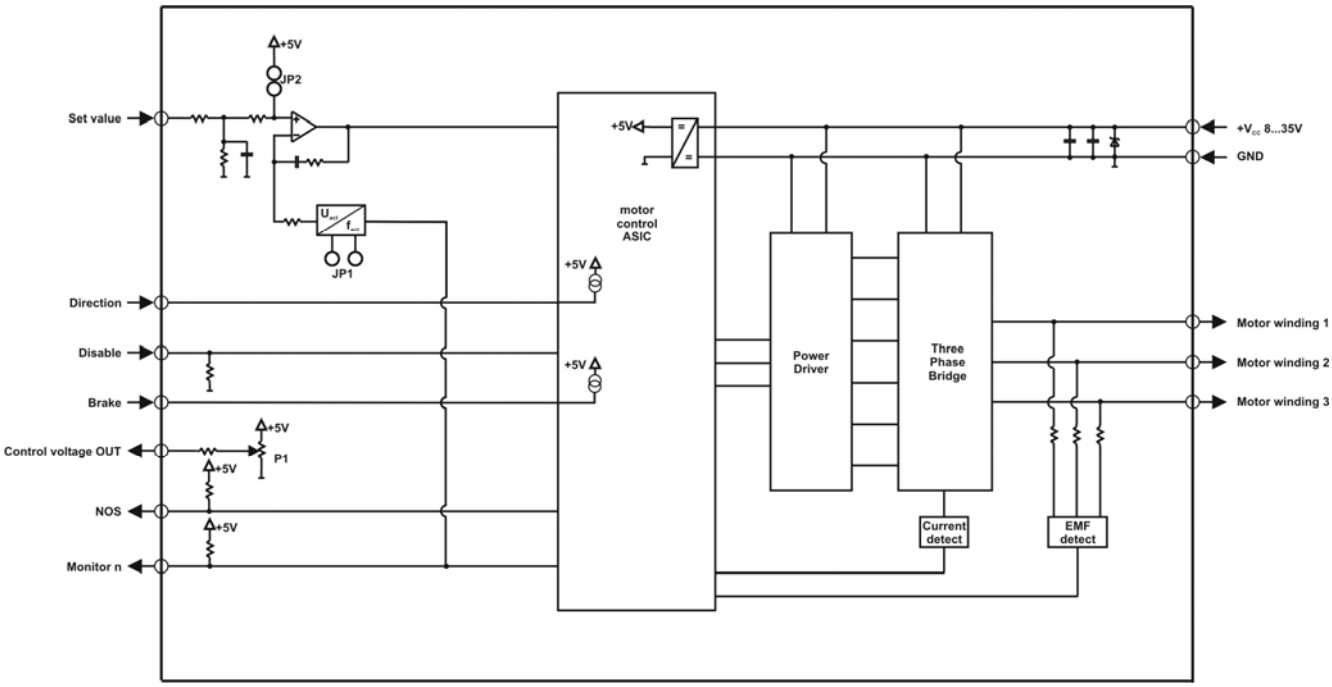
1	Motor winding 1
2	Motor winding 2
3	Motor winding 3
4	Neutral point Y (not used)

Flex print connector	4 poles, top contact style
Pitch	1.0 mm

Note:

Motor terminals matching, e.g:	maxon EC∅14 Flat motor sensorless maxon EC∅20 Flat motor sensorless maxon EC∅32 Flat motor sensorless maxon EC∅45 Flat motor sensorless

8 Block Diagram



9 Dimension Drawing

Dimensions in [mm]